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THE LIMITS OF ORGANIC EVOLUTION.

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THE theory of evolution implies a past, a present and a future. Since the time of Darwin the past and present of the organic world have been studied with the result of showing that the history has been one of evolution. Having now reached this conclusion, and having discovered many of the laws of advancement in living nature, we are getting into a position where we may begin to study the future. It is the object of this paper to indicate certain limits in development toward which the organic world have long been tending.

The idea of evolution implies that there has been a gradual rise in the scale of organisms from the lowest to the highest. But when palæontologists have attempted to show this gradual rise by a study of fossils they have had much less success than the theory of evolution would lead us to expect. That there has been a general advance from the earliest fossils in the Silurian until now, seems unquestionable. But instead of being the most palpable result of study, this advance is so obscure as to cause surprise to all who have attempted to make it out in detail. Darwin expressed his surprise at the lack of evidence, and the difficulties have increased rather than decreased since he wrote. In some groups there has been an undoubted advance; the vertebrates, for instance, showing this in a marked manner. In a majority of groups, however, we do not find it, for while the animals have not in any case remained absolutely stationary, the development, as a rule, has consisted chiefly in the increase and diversity of species and genera. It is a matter of continual surprise to naturalists to find constantly increasing evidence of the great diversity of life which must have existed in the Silurian era. With the advance of our knowledge of these earliest fossiliferous rocks, new groups are constantly being added to the already extensive fauna. Our knowledge of these times is still very scanty, but even now we know that the fauna was highly developed. All of the subkingdoms of the animal world were represented, about five-sixths of the orders and suborders of the present time, many families and a few genera. Bearing in mind the necessary incompleteness of our collections, we must conclude that this fauna contained representatives of a large proportion of the animals now existing. Nor were the various groups represented by these lowest types simply. The Cœlenterata contained Hydrozoa and Actinozoa; among echinoderms we find echinoids; among mollusks we find cephalopods; among Arthropoda were Tracheata in the shape of scorpions. And while these types were not developed as highly as they are now, their mere existence is enough to indicate that already a large advance in the evolution had taken place. If this is the case it becomes plain that evolution since that time has been almost entirely confined to the elaboration of the groups then existing.

Now we are not at liberty to assume an indefinite amount of time prior to the Silurian. Of course it is impossible to say just how long a time elapsed between the origin of life and the Silurian, but it seems hardly possible that it could have equaled the time since then. But upon evolutionary theories the animal kingdom must have developed during that period from the lowest unicellular condition to the complex and diverse fauna of the Silurian. When we consider, therefore, that during this time all of the important groups of the animal kingdom* arose, and that none have arisen since that time, it becomes quite evident that evolution must have progressed with greater rapidity at that time than it has since. This conclusion is no new one, for many naturalists have seen the necessity of making some such assumption. It will, indeed, be generally acknowledged that evolution at earlier times was more rapid than at present.

Now it follows as a direct result of this fact that the evolution of organisms is approaching an end, and that it will eventually cease. If the rapidity of evolution as a whole has been decreasing since the beginning of life, it is evident that unless something

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*[It is very doubtful whether there were any Vertebrata during the Silurian.—*Ed.*]

occurs to begin the process over again, evolution must eventually cease.

This would lead us to the conception of the animal kingdom as not unlimited in the extent of its development, but as having a definite end. This may be made clearer by two comparisons. First, consider the life of any individual. This begins with the fertilization of the ovum. Fertilization seems to endow the ovum with a large amount of vitality, or what has been called growth force. This growth force causes the ovum to begin to divide and grow with great rapidity, and the changes which take place as the result of this invigoration, are very great during the early part of the development. But immediately from the first the rapidity of this growth begins to decrease. As the individual becomes older its rate of growth becomes less and less, the invigorating force gradually expending itself, until finally a condition is reached where no further growth takes place. For some time now the animal remains in a state of equilibrium, but finally begins to go down hill and dies. A better comparison still may be found in the life of a tree. Here also we find at the outset a rapid growth and advance, very early the rapidly growing stems give rise to buds which are to become the great branches of the coming tree, and in a very short time the shape of the tree is determined by the growth. All of the larger branches have appeared, and they have already given rise to many of the smaller ones. But here also the rate of growth diminishes, and as the tree becomes older and larger it grows less rapidly. Finally at a certain size its growth practically stops. It does not of course actually cease to grow. It is continually producing new leaves, new twigs; old branches are being in some places expanded, in others they are dying and disappearing. There is thus a constant change and growth taking place in the various parts, but the growth of the tree as a whole has ceased. For a long time, perhaps the tree may remain in this condition, but little by little the process of decay encroaches upon that of growth, and finally the tree dies.

These examples are of course simple analogies, and it is a question how far they may be regarded as applying to the animal kingdom as a whole; but there are many facts which indicate that the history of the organic world as a whole is parallel to the life of the individual, in part at least. That the relations of animals in the world are to be looked upon as that expressed by a branching tree is now perfectly demonstrated. That all of the great branches of this tree, as well as many of the smaller ones, had made their appearance at the time of our first record of life, is also proved. That evolution since that time has consisted chiefly in the elaboration of these branches by increasing their division and the diversity of species and small groups, is becoming more and more evident. That there has been a slowing up of development in recent times is a fact which is strongly forcing itself upon naturalists; and the conclusion has found expression in the statements sometimes made that no new species are arising to-day, or that the present is a period of comparative rest. The same general principle is taught from embryology, for very early in their history do embryos become separated into the subkingdoms to which they belong, while more and more slowly does the separation into the smaller groups take place. All of these facts together strongly indicate that the illustrations used above are in part real illustrations, and that the whole animal kingdom must be looked upon as an individual starting its history with a vigorous growth which is gradually expending itself. Whether or not this growth will reach a limit, and whether or not it will eventually cease so that the animal kingdom will disappear, it is our purpose to consider.

That the organic world is approaching a limit to its development is a conclusion which does not depend upon any vague idea of growth force for its support; for a little thought upon discovered laws will clearly show us that there must be a limit to advance. The best definition which has ever been given of the grade of structure of animals is the degree to which differentiation of organs is carried. Evolution as it tends to raise the grade of animals is constantly increasing the amount of differentiation. A distinction must be made, however, between differentiation and specialization. Evolution sometimes results in retrogression, and in these cases differentiation becomes less rather than greater. Evolution does not, therefore, always produce a greater differentiation, but in all cases, even in those of retrograde development, it does produce a specialization of parts, and we may rightly regard evolution in the animal kingdom as a process of specialization. Now it is plain that this process can not go on forever. A low undifferentiated unspecialized organism has an infinite possibility in its lines of specialization. A simple spherical mass of cells, the supposed common ancestor of the animal kingdom, may be modified in a very great variety of directions, each of which may give rise to a different type of animal. This possibility lies in the fact that it is as yet undifferentiated and unspecialized. But just as soon as it does become modified in any one direction the possibilities decrease. Some of the descendants of this ancestor becoming vertebrates are forever precluded from becoming anything else; others becoming mollusks must remain mollusks forever, with all of their descendants. And as later descendants become further modified in any direction into definite types, the chance for future modification becomes rapidly less. It is only the absolutely undifferentiated which has infinite possibilities, for as soon as a single step is taken in any direction they become finite. Now it is plain, since evolution does not retrace its steps, that with every step in advance the possible lines of development become less and less. All the descendants of the vertebrate line must conform to the vertebrate type. The vertebrate becomes separated into fish, reptile and mammal, and the individual of each group is still further fettered in its development by the special line which its ancestors have taken. The descendants of the animals which have started the order of birds can not take any new line. They can develop to perfection this type, but there they must stop. And so on, with every advanced step the possibilities of expansion are constantly decreasing.[1]

Now a continued specialization of this sort is sure to reach a limit eventually, it must run to extremes and then stop. Development must reach a position where further advance is no longer possible. Let us illustrate this principle by a concrete example. A five-toed appendage is an unspecialized form which we may conceive as modified in many directions. It may become a grasping organ or a supporting organ or a swimming organ, etc. In the group to which our ruminants belong this appendage has become a supporting structure. In this same group there has further been a tendency to rise upon the toes, in such a manner that instead of walking on the soles of the feet and palms of the hands, the animals in question walk more and more upon the fingers and toes. When this peculiarity first began to manifest itself, the mammals had five toes. As it became more and more marked the shorter toes were little by little lifted from the ground and became of little or no use. In successive ages we find the shorter toes becoming smaller while the middle toe becomes larger. This line of specialization has continued until it has reached a limit in the horse, which has lost all but one toe on each foot, and walks on the extreme tip of this toe. Now it is perfectly evident that a limit has been reached in this case. The horse may perhaps in the future lose the rudimentary splint bones which still remain, but he can not lose his last toe; and it is therefore impossible to conceive any further development of the horse in this direction. Now the same principle will apply to all other lines of specialization, although we may not always be able to see what this limit may be. Physical laws would of themselves set limits to every line of advance, even if there be no such limits determined by the organism itself.

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[1] This idea can be found fully expressed in the writings of Professor Cope.

It is easy to find examples which will show that such has been the general history of groups in the past. Some have reached the extreme of their development in the distant past, and have ceased to advance or disappeared. Others seem even now to be at the summit of their advance, and others still are yet advancing. The line of development represented by the trilobites has completely exhausted itself. It rapidly approached its limits even in the Silurian, and then began to dwindle away and has disappeared completely. The brachiopods had also at this time reached their point of highest specialization, and became a highly developed group even at this early age. Since then they have remained stationary as to their organization, having steadily decreased in numbers, and the few that are left show no advance over the Silurian forms. The cephalopod mollusks gradually increased in complexity during the Palæozoic, and finally a limit of the shelled forms was reached in the ammonites of the Jurassic and Cretaceous. The culmination was followed by extinction. Meantime a second line of development began, that of the naked cephalopods, and this has gone on advancing until the present time. The decapod Crustacea represent a group which is even now near its culmination. From their first appearance in the Carboniferous there has been a tendency toward concentration of organs toward the head. As this specialization advanced the abdomen became smaller while the head region became larger. Finally in the crabs, which appeared in the Jurassic, everything was concentrated into the head region; the abdomen being little more than a rudiment. Evidently we are here near a limit, and we may look upon the crabs of to-day as the culmination of the special line of development which has characterized this line of animals. The vertebrates in general have been continually advancing during geological times with a continued increase in specialization and in multitude of types. But even here there has been the same story of limitation. The ganoids culminated in the Devonian, and have advanced no farther. One great line of reptiles reached its limit in the Jurassic. And so everywhere. The study of every group teaches that the past history has been a gradual specialization, which approaches a limit. In many cases in the past this limit has been reached and advance ceases; while in others animals are still on their road toward it.

It is plain, therefore, that the evolution of the whole animal kingdom is slowly but inevitably approaching an end. With every advance in differentiation the possible lines of development decrease, and since the actual lines followed are tending to run themselves out, the whole must eventually stop.

Recognizing, then, that there must be a limit to advance, we must next ask the question, whether after this limit is reached the animal kingdom will become extinct; whether, like an individual, it will die of old age? And here we must distinguish two questions. First, is it not possible that animals which have remained unspecialized during all times, should give rise constantly to new lines of development, and thus be a perpetual source of new forms? Second, will the present groups, after reaching their culmination, become extinct or simply remain stationary?

That there is a theoretical possibility of the origin of new types cannot be denied. New types, *i. e.*, new lines for specialization, can arise only from undifferentiated forms. But such undifferentiated forms still exist in great numbers. Even the most unspecialized form of all, the unicellular animals, are abundant enough, and in all groups we are acquainted with more or less generalized types. Theoretically, then, there is no reason why any of these forms should not expand itself and thus form an eternal source of new world forms. So long as the unspecialized forms do not become extinct, we cannot deny the possibility of an infinite number of future subkingdoms, which would, of course, make the animal kingdom an example of never-ending evolution.

But all of our evidence indicates that such a future is probably not a practical possibility, even though, as far as we can see, it may be a theoretical one. All biological studies point strongly to the conclusion that instead of several points of origin the animal kingdom has had only one. The subkingdoms have not arisen independently from the Protozoa, but have all had a common ancestor, the gastrula, and this means that only once has the unicellular form given rise to important lines of multicellular descendants. Though the Cœlenterata stand very near this primitive unspecialized form, there is no evidence that it has the power of further differentiation; but on the contrary, all tends to show that whatsoever differentiation of this simple type ever did take place, to give rise to the subkingdoms, occurred before the Silurian. Since palæontology shows us that no new great types have arisen since the Silurian, it is plain that all of the expansion of the simple unicellular form must have taken place before the Silurian. And coming through the later ages we find evidence the same in its tenor. The conclusion everywhere seems to be that when a generalized form has given rise to one or two lines of development, it either disappears or loses its power to originate new forms. Every step of palæontology carrying existing groups farther and farther back in the geological ages adds force to this general conclusion. Every bit of evidence which indicates a fundamental unity of the animal kingdom testifies to the same. Without questioning the theoretical possibility that any or all of the existing more or less unspecialized forms may in the future develop, we must acknowledge that the probability is against it. Nothing in history indicates that these groups retain power to expand, and there is, therefore, no reason for thinking it a possibility in the future. Remembering what a large number of groups we are learning to trace back to the Silurian, remembering that development has consisted, in the later geological ages, simply in the expansion of groups appearing long before, we must conclude that the power of the undifferentiated forms to expand into different lines of development disappears very early in their history. While then we cannot deny the possibility of an indefinite future development from the existing generalized types, it is certainly improbable that any new great groups will arise. Man, seizing upon the last undifferentiated faculty, the intellect, is developing this to extreme, and will probably be the last type to appear.

The second question, concerning the probability of the various groups becoming extinct after reaching their culmination, is not so easy to answer. It is certainly possible to conceive of them as remaining stationary at their culmination, neither developing further nor becoming extinct. Undoubtedly the history of the past shows that after any group reaches an extreme of specialization it does not remain stationary, but begins to decrease in numbers, finally to disappear. But the number of groups which have thus become extinct is not very great, and it is a question whether it is justifiable to claim that they really represent a general tendency. It is certain that disturbing causes which have acted in the past to produce extinction will grow less and less in the future. We can see that extinction in the past has been due to the inability of these extreme forms to adapt themselves to new circumstances with sufficient readiness. Of course when all of our present groups shall have developed themselves to extremes, they too will be unable to adapt themselves to new conditions, and would doubtless become extinct if they were called upon to meet adverse circumstances. But it is an acknowledged fact that physical changes are much less rapid now than they were formerly, and that they are constantly diminishing. If this is the case the developed extremes of the future will not be called upon to meet such changes in condition as those which have induced extinction in the past; and they may even then be able to undergo such slight modifications as will enable them to meet the slight changes in condition. Moreover, in the past extinctions have very generally occurred because animals have been unable to contend with the new and more vigorous forms which were capable of a more rapid modification than the older ones. But as we have seen, the number of possible new forms is constantly decreasing, and the time must come when it is no longer possible for new forms to arise to crowd the older ones out of existence. With almost stationary physical conditions, and with no new rivals, it may be that the animal kingdom is approaching a condition when, for reasons which we have seen, it cannot advance, and when there will be nothing to cause extinction, and it will therefore remain stationary.

There is one new condition, however, which is to have a prodigious influence upon the evolution of the future. The influence of man on the animal kingdom cannot be computed, but it is probable that in many respects it will be a death blow to its evolution. Man is rapidly causing the extinction of almost all land animals, at least the larger ones. As the frontiers of civilization are being extended further and further into the uninhabited regions, he is driving out of existence all of the larger animals and many of the smaller ones. We have only to look ahead a comparatively short time to see the extinction of all land animals except such as man may preserve for his own use. To what extent this may apply to other animals, to insects, marine animals, etc., is not clear. But in the highest group of animals, the vertebrates, it is pretty clear that man is eventually to bring about not only the end of advance, but also the practical extermination of all animals except such as he especially preserves.

With all of these considerations together it seems perfectly plain that we must look upon the evolution of the animal kingdom as definitely limited and approaching an end. The tendency of specialization to advance to extreme limits, the impossibility of the further adaptation of these extremes to new conditions, the significant fact that no new forms of importance have arisen during all the later geological ages, the great influence of man in causing extermination of all sorts of animals, all these point to the same end. Just as evolution began in time, so it will end in time, and we must look upon the animal kingdom as progressing toward a limit. When this limit is reached, either there will follow a gradual extinction through a diminution of vital power, or if this be not the result, a stationary condition will ensue in which such animals as man has left in existence will remain unmodified until the progress of physical changes makes this world no longer habitable.